Simulating bubbles with scalar field fluctuations

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During the electroweak phase transition, the Higgs field decays from one value to an energetically more favourable value, thus breaking its symmetry. In the Standard Model (SM) this is a cross-over. However, if we assume this transition to be first-order, which is possible in many SM extensions, there exists a potential barrier between the initial state and the energetically favourable state. Consequently, the first-order electroweak phase transition must occur as a result of quantum tunneling or, in the field-fluid model, via thermal fluctuations. This could provide an explanation for baryogenesis and the resulting gravitational waves are detectable by the future gravitational wave detector LISA.

The propagation of this transition throughout space creates bubbles of space where this transition has occurred and the $W^{\pm}$, Z and Higgs bosons have obtained their mass. Depending on their velocity profile, we can classify these bubbles as deflagrations, detonations or hybrids. The speed of sound turns out to be an important divisor for this classification.

In order to accurately simulate the evolution of a bubble the variables are discretised using the leap-frog method. This means that state variables live in the middle of zones while derivative values live on the edges. Furthermore, the Bag Model is an often used approximation to the potential which is needed to determine the temperature and the pressure. Finally, advection caused by the flow of the fluid can be used to determine the time evolution of the energy and momentum densities.

Scalar field fluctuations are introduced as noise into an existing 1D simulation in spherical coordinates. The noise introduced is normally distributed and the amplitude is based on the friction and local temperature. Unfortunately, for now, this results in the noise dominating while no phase transition occurs. This is due to the early collapse of the bubble. There are several possibilities to improve this, which include decreasing the standard deviation of the noise, adding the noise after the field has had a chance to evolve and initialising the bubble using a solution from previous simulations.